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AUTHOR Mansell, Jack; And Others
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ABSTRACT

National competitiveness depends in large part on the practical application of technologies. Educational planners must, therefore, identify key (newly emerging) topics in science and engineering that are likely to have a major evolutionary effect on industry and incorporate these areas into existing vocational and technical curricula. Because industry adopts new techniques faster than the education system, educational institutions working to prepare students for an uncertain future must teach them fundamental principles, including design, that underpin the development of specialist expertise as well as economic awareness and associated management and business skills. A regular review of technology-based curricula is necessary to ensure that course content and teaching methods are up to date. Each educational institution should, in consultation with its industrial and commercial partners, identify which changing technologies should be incorporated into vocational curricula. Emphasis should be placed on practical examples and on the development of economic awareness in all areas of the curriculum. The key technologies concept is intended to call attention to attitudes toward technology rather than to provide a shopping list" of new technologies. (Appendixes contain discussions of the United Kingdom's import problem, the problem-solving approach, and robotics and advanced manufacturing technology as a practical example of the teaching of a key technology. (MN)

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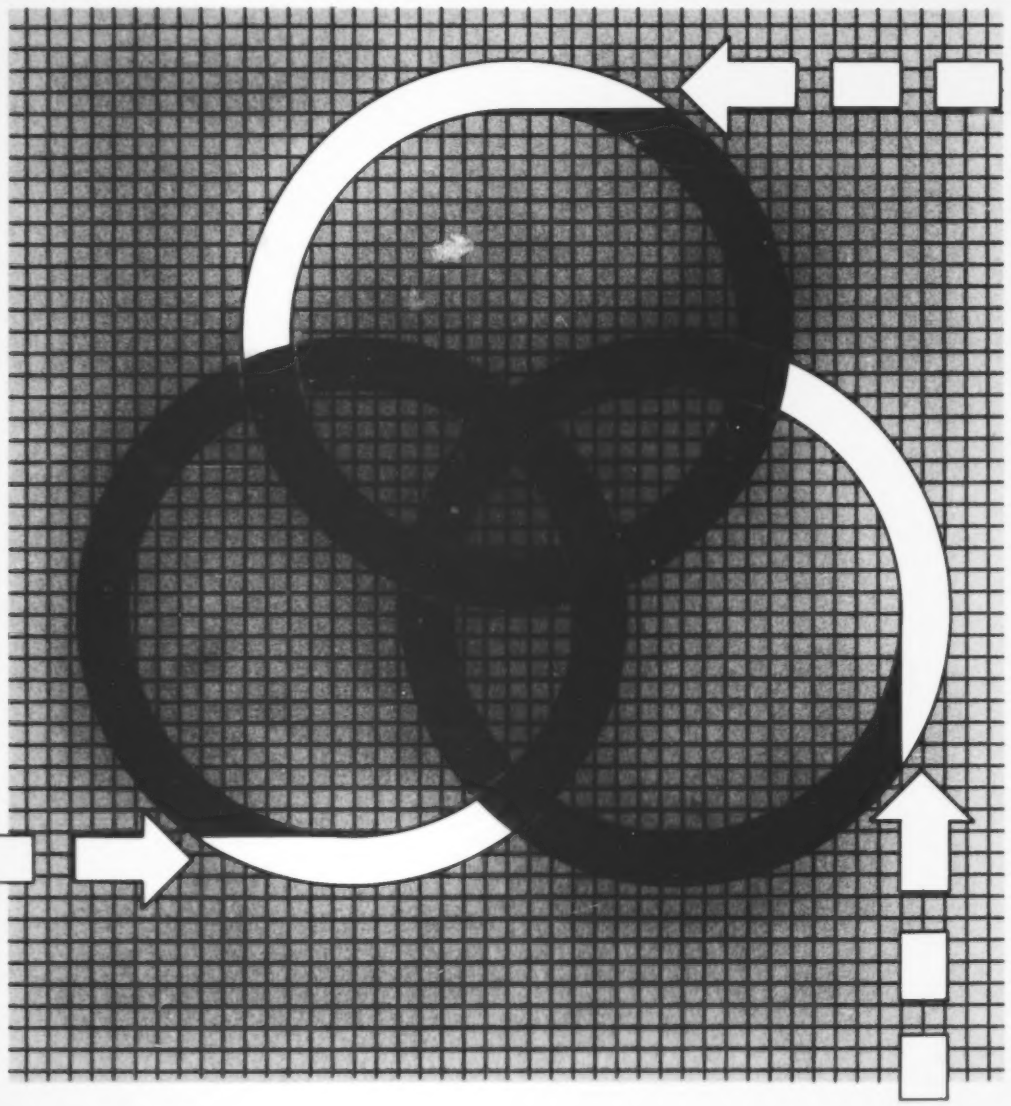
THE KEY TECHNOLOGIES

SOME IMPLICATIONS FOR EDUCATION AND TRAINING



AN OCCASIONAL PAPER BY THE FURTHER EDUCATION UNIT AND THE ENGINEERING COUNCIL

CE 050 037

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FOREWORD

Considerable progress has been made in improving efficiency of British industry but there is still a long way to go, especially considering that every year since 1983 the UK has been a net importer of manufactured goods. Many recent reports have drawn attention to the need to improve education and training as one of the many moves required to compete internationally.

We believe that the concept of 'key technologies' has important implications for all providers of education and training, especially in the formation and continuing education and training of engineering technicians, technician engineers and chartered engineers. Industrial and commercial employers need individuals with good technical, commercial and interpersonal skills who are able to keep up to date with changes in working practices and technology. The concept of key technologies is also important for individual engineers and technicians in planning their future.

This paper aims to explain key technologies and their relevance to all those involved in education and training.

Allan Ainsworth
Chairman
Further Education Unit

Sir Francis Tombs FEng
Chairman
The Engineering Council

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EXECUTIVE SUMMARY

National competitiveness depends, in part, on the practical applications of technology and so those technologies which are likely to have most impact in the future need to be identified. Industries are encouraged to seek out these 'key technologies'.

The Engineering Council introduced the concept in *A Call to Action*[1]. **Key technologies are defined as newly emerging topics in science and engineering which are likely to have a major evolutionary effect on an existing product or process or may lead to a revolutionary new product or process**.

The key technologies – specific to each industry – have, by definition, the potential to improve competitiveness. Engineers and technicians must not only recognise their importance but must also have the educational background to be able to work with these technologies which may appear to be remote from their own specialisation. In this way the key technologies provide a guide to education and training in the longer term.

Industry adopts new techniques faster than the education system and so it is impractical to rely on frequent changes in styles of education as a means of ensuring an up-to-date workforce. In preparing students for an uncertain future, educational institutions need to enable them to learn fundamental principles, including design, which underpin the development of specialist expertise as well as economic awareness and associated management and business skills.

A regular review of technology-based curricula is suggested as a means of ensuring that course content and methods of learning are up to date. Each educational establishment should identify, in consultation with its industrial and commercial partners, which of the changing technologies it should use as examples in its teaching. The emphasis should be placed on practical examples and the development of economic awareness at all levels in the curriculum.

The key technologies concept is intended to draw attention to the attitudes towards technology rather than provide a 'shopping list' of new technologies. As industry is so wide ranging, it is an individual's responsibility to establish which technologies are relevant to his or her area and should therefore be considered key

technologies. Those working in industry and commerce need to have learned general principles and to have the ability to select and understand the key technologies in their business area. This depends upon a broadly based education as a foundation for peaks of achievement in specialist areas.

ACTION CHECKLIST

1. Staff awareness of key technologies should be raised at all levels.

2. Current programmes and curricula should be regularly reviewed.

3. Staff training should be carefully planned to include the following:

   - systems approach;
   - flexible delivery;
   - team working and interpersonal skills;
   - economic awareness;
   - modern design processes.

4. Sample projects and case-studies should be developed to illustrate the key technologies.

Illustrations of the wide range of technologies used throughout industry.

Modern surgical techniques are dependent not only on the skills of the surgeon, the anaesthetist, their respective teams and the general nursing staff but also on a wide range of sophisticated medical products, and equipment. These include sterile single-use items in plastics and latex, surgical instruments and implants as well as the design, manufacture and installation of complete technical service systems for the operating theatre.

(Photograph: Smiths Industries plc)

Welding techniques and robotics skills have been combined in the Tomkat arc welding robot.

(Photograph: Northern Engineering Industries plc)

1 TECHNOLOGY AND COMPETITIVENESS

1. It may be possible to anticipate many short-term developments in engineering, but over longer periods, say 10-20 years, prediction is less certain. It is essential to prepare for the future by creating an environment in which engineers, technicians and others can adapt easily and flexibly in creating competitive products.

2. The United Kingdom depends upon international trade for its long-term economic success and the nation's standard of living is dependent upon the trade balance of manufactured goods, raw materials and services. Many recent reports have commented on the need to redress the balance of payments in manufactured goods. This case is developed in Appendix 1.

3. A close look at some successful imports shows they are competitive because they are well designed, reliable and appealing and factors such as quality, delivery and physical appearance are seen by consumers to be as important as relative cost when comparing products. Market sophistication is broadening the range of imported products, which is in turn made possible by the increased speed with which the production of advanced high technology products, and established products using new high technological processes, can be transferred to the newly industrialised countries. Therefore, more rapid development of new products and processes in Britain is necessary if we are to develop a commercial edge. Hence the relevance of the Advisory Council for Applied Research and Development's advice in 1986:

> 'The export opportunities which maintain standards of living are those which offer high value added per unit of employment; products with a knowledge base in advanced technology which can be sold on world markets at favourable terms of trade. The products of relatively mature technologies are increasingly the preserve of low-wage newly industrialising countries with which the UK has little realistic prospect of competing without a drastic fall in living standards.'[1]

4. Innovation is necessary for the creation of new products and processes, and for the improvement of existing ones. Mature industries can be rejuvenated by the introduction of modern management and manufacturing techniques, but the long-term profitability of companies depends on the sale of products and services. A proper balance is needed between new products, middle-aged products and products approaching the end of their life, while the factors influencing the development and marketing of new products need to be understood if long-term competitiveness is to be achieved.

British Gas inspects gas and oil pipelines using intelligent pigs (pipeline inspection vehicles). The larger pig (42 inch diameter) is shown alongside the smallest pig which has an 8 inch diameter. In order to fit the inspection system into such a small volume a new concept in magnet design had to be developed and the electronic processing components integrated with the recording module.

(Photograph: British Gas plc)

The examination of a backside gold-coated silicon wafer. The microelectronics industry relies on engineers understanding and using technologies at the materials levels.

(Photograph: The BOC Group plc)

5. An advanced industrial society depends on the skills which are developed in further and higher education establishments, research institutions and industry. Comparison with other industrialised countries shows the shortfall in the number of individuals, including engineers and technicians, who are educated and trained to meet British industry's demands.[4] While the supply of a skilled workforce is the responsibility of the education system and industrial training organisations, industrial leaders should, for their part, enumerate their requirements and co-operate with the educational institutions in developing the curriculum to their mutual benefit. Highly competent staff are required not only to work directly in industry but also to work in the services, such as education and training and government.

2 SKILLS FOR THE FUTURE: THE KEY TECHNOLOGIES

6. The present range of scientific and engineering disciplines has been developed from the historical constraints of academic study. Consequently individuals tend to study and work only in their own particular discipline.

7. Although discipline boundaries may be useful in defining areas for professional activities, they must not become barriers. Interdisciplinary techniques are being developed which open up opportunities for a wide range of products and processes, while interdisciplinary subject areas are of particular interest to engineers who wish to bring new ideas to the market and to meet existing market needs in an innovative way. Often an apparently complex problem may be solved by a method taken from another discipline.[4]

8. The important technologies for improving industrial competitiveness are called 'key technologies' in this paper. Key technologies have the following characteristics:

- they are often, though not exclusively, from interdisciplinary areas;
- they are innovative topics in science or engineering;
- they will have a major evolutionary effect on an existing product, or may lead to new products;
- they will have a wide range of applications in products and processes resulting in high added value.

9. The key technologies are the supporting structure for designing new products and processes and so form an element of competitiveness. They should be considered in relation to the activities of research, design, development, production, finance, quality, marketing, sales and service.

10. It is essential for each industrial company to know the areas of technology which are most appropriate to its business.[5] This determines the competitive position of the company's products. Technologies may be classified into three groups:

i) materials: the building blocks of products;
ii) components: the sub-assemblies of systems;
iii) manufacturing and process: the assembly techniques which combine elements from the other areas.

11. There is some overlap between these groups, especially as the materials technologies underpin developments in the other two groups. The benefit of defining groups of technologies is that business strategy can be linked to the most appropriate group for innovation. Thus each

company can seek out the key technologies applicable to its business and technical area and thereby avoid the danger of trying to maintain awareness by making random attempts to follow the latest developments.

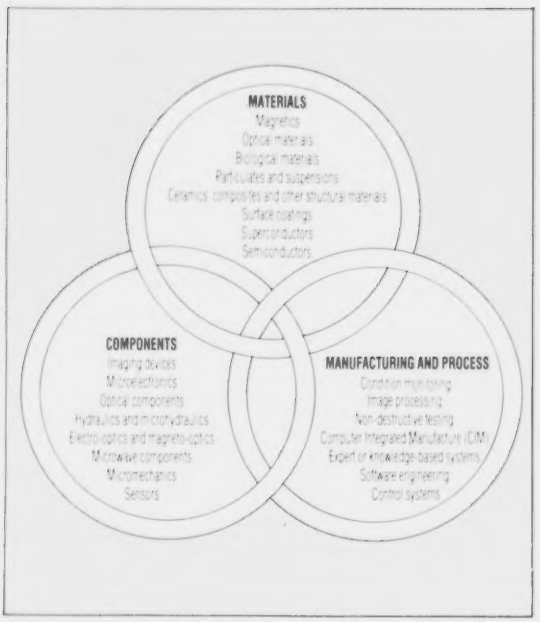
12. Figure 1 shows some examples of key technologies arranged into these groups. No attempt has been made to compile an exhaustive list because such a list would soon need revision and updating.

13. In considering the key technologies it may be helpful to look at some earlier innovations which have had a sufficient number of applications to be called 'key' technologies (Figure 2):

a) *Welding* – The joining of materials by use of a molten material is now so commonplace that its impact on industrial processes is taken for granted. Most industrial products contain welded joints, although the acceptance of welding in ships and aircraft took several decades. Recent developments include welding of plastics and polymers and solid-state diffusion techniques.

b) *The thermionic valve* – Although now overtaken in most applications by semiconductors, the thermionic valve made electronic systems possible and subsequently the development of the computing and communications industries. High power applications, for example in television transmission, still require thermionic valves.

FIGURE 1 – EXAMPLES OF KEY TECHNOLOGIES



Examples of some current key technologies are as follows:

a) *High density magnetics* (materials) – The high magnetic strength of samarium oxides has been

FIGURE 2 – A COMPARISON OF PAST AND CURRENT KEY TECHNOLOGIES

GROUP		EARLIER EXAMPLES OF KEY TECHNOLOGIES	EXAMPLES OF TODAY'S KEY TECHNOLOGIES
Materials	The building blocks for products	Welding Silicon semiconductors Oil-based polymers Case hardening	Biological materials Group III/V semiconductors Ceramics Ion beam implantation
Components	The sub-assemblies of products	Thermionic valves Radio circuits	Optoelectric devices Mechatronics Sensors
Manufacturing and Process	Techniques for assembling systems from materials and components	Numerical control	Image processing Flexible manufacturing Expert or knowledge-based systems Condition monitoring

known for many years, but they were not incorporated into commercial products because of their high unit cost. However, a reappraisal of loudspeaker design enabled leading Japanese companies to develop small, lightweight, hi-fidelity earphones. The success of these earphones was reflected in the large worldwide sales of of personal stereos.

b) *Fibre optics* (materials and components) – The use of fibre optic cables to carry light signals has opened up the possibilities of optical-based communication. This has the advantage of increased bandwidth and signal capacity.

c) *Condition monitoring* (manufacturing and process) – Techniques for monitoring machinery,

structures and equipment while in operation reduce the need for 'downtime' and enable maximum output from process plant. Substantial increases in competitiveness can be achieved.[6]

d) *Composite materials* – Rotor blades used on high-speed helicopters have been manufactured from advanced composite materials; they also take advantage of a new understanding of air flow theory and practice.

e) *Superconductors* (materials) – The race is now on to discover more ceramic compounds, typically based on barium, copper, oxygen and yttrium, which become superconductors at relatively high temperatures. Superconductors have many applications in electric or electronic circuits or where magnetic fields are needed. Now that superconductors can be produced relatively easily, applications are being vigorously sought for this key technology. The techniques of a technology that is only a few months old can be illustrated in schools and colleges.[7]

14. While it is difficult to pick out the individual technologies which may be of the greatest significance in the future it is expected that developments in materials technology are likely to lead to a large number of innovations. Raw materials are becoming more scarce and expensive and market sophistication is demanding increasingly advanced and competitive products. Therefore, the selection and use of the most appropriate materials is a necessary skill:

> 'The failure of the UK to grasp current opportunities in materials technology would lead to reduced competitiveness in world markets and future reduction in the manufacturing base of the UK.'[8]

15. The object of drawing attention to the key technologies is to show their effects on the improvement of existing products or the development of new products thus raising competitiveness. For example, new ceramic materials containing silicon, aluminium, carbon, nitrogen, oxygen and zirconium are light, stiff, and corrosion- and wear-resistant. They have current applications in gas turbine and reciprocating engines, cutting tools and the process plant industry. Future developments in other areas, for example bio-engineering, may reveal many applications where these materials can have a considerable effect on competitiveness. Sometimes apparently mature or traditional industries can be rejuvenated by the application of technology; the development and commercial applications of steels have been increased by investment into materials technology. Modern steels are used under severe conditions and are subjected to much greater loads than

steels manufactured thirty years ago, but because the commercial implications of these steels were not fully appreciated in Britain, steel manufacturers reduced their capability to produce high value steels, and now many of these products are imported.

16. The challenge for engineers of all disciplines is to be aware of developments and to communicate effectively with their colleagues from other specialist fields. Technicians and craftsmen/women must also appreciate that they will be working with components manufactured from non-traditional materials.

The matrix approach to priorities

17. The Technology Requirements Board of the Department of Trade and Industry has proposed an approach to priority setting for research and development based on the highlighting of 'key generic technologies'. The approach considers a matrix, relating product areas in which the UK is successful (or is well placed to be successful) in penetrating world markets, to the technologies necessary for the future success of these product areas. The 'key generic technologies' which have been highlighted are:

- information technology (applicable to most industrial sectors)
- advanced manufacturing technology
- materials technology
- biotechnology[9]

18. While it may be appropriate to define 'key generic technologies' as a means of directing national support of research and development into specific areas, at the company level it is necessary to ensure that the subjects for new product and process development are relevant to the industry and its market. Key technologies, as defined in this paper, are those specific to each industry which have the potential to improve competitiveness. The key technologies relevant to a specific company may well come from a much wider range of developments than those contained in these four generic areas.

3 SOME IMPLICATIONS FOR EDUCATION AND TRAINING

19. By promoting and developing the concept of key technologies, it is hoped to draw attention to the continuing need to consider future developments in science and technology. This is of importance to:

a) those in industry and commerce, who must be able to respond to a changing market place by creating products and services which meet market needs;

b) individuals, who must take initiatives to keep up to date through the medium of continuing education and training (CET);

c) providers of education and training, who must respond to changing vocational needs of two types of students:

i) those whose work is directly related to science and technology. (There will be new subjects and new applications which will have direct influence on courses in engineering, pure and applied science and business studies);

ii) other students – who may be in the majority – who will be affected by the wider application of key technologies. Their education should include the development of positive attitudes towards these key technologies and an understanding of their effects on society and on the economy.

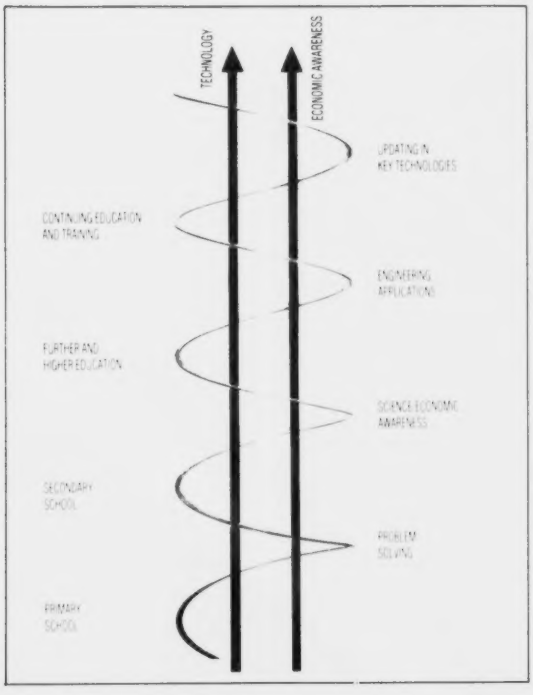
The spiral curriculum

20. The underlying message in this paper is that the key technologies have an economic impact. Provided the definition of economic impact is not simply related to profit, but to society as a whole, the link between economic awareness and technology should be promoted throughout school, further and higher education and should recur at all stages of the curriculum. (The 'spiral curriculum' as developed by Bruner and others[10] may be a possible model to illustrate this concept.)

21. The spiral model (Figure 3) shows the recurrence of a theme at various levels throughout the curriculum and may be used to illustrate the following points:

- a discipline must be characterised by basic organising ideas if it is to be spiralled;
- the wholeness of the discipline is demonstrated by the subject at one level being taught in the context of what has gone before and what will be taught later;
- students are continually introduced to the more powerful ideas that are unwrapped as the discipline is explored.

FIGURE 3 – THE SPIRAL CURRICULUM RELEVANT TO THE KEY TECHNOLOGIES



22. The application of the education spiral illustrates the unifying theme of the key technologies by linking technology and economic awareness. At lower levels in the spiral the problem-solving approach provides opportunities to introduce technology and economic awareness into many other subjects.

23. An interdisciplinary, problem-solving approach in the earlier stages of the curriculum provides opportunities to introduce technological and economic awareness into the whole range of subjects and provides a good background for the later development of these ideas. The primary schools project sponsored by The Engineering Council and SCSST[11] facilitated such an approach to the teaching of science and technology.

24. At the secondary level, 'Balanced science for all', promoted by SSCR, encourages an experimental and process-based approach aimed at broadening the teaching of science and technology.[12] Thus all pupils of compulsory school age should have the opportunity to develop a basic knowledge of, and positive attitudes to, science and technology and their impact on society. At the earlier stages of education the concept of key technologies can be introduced by a retrospective view of now familiar examples (e.g. Faraday's generation of electricity).

25. This document tends to emphasise technology in engineering terms. However a wider definition of technology is necessary if a comprehensive and equal opportunities approach is to be

applied. Home Economics and Rural Studies can be as intrinsically 'technological' as Engineering Science.[13]

26. Post-16 students and those in FHE will often wish to develop specific aspects of science and technology to a higher level. The opportunity of promoting the economic impact of technology, interdisciplinary study and project work should be encouraged throughout the students' formation process.

27. By definition, key technologies are continually developing; the 'spiral curriculum' shows the links through to continuing education and training and emphasises the need for engineers, technicians and others to keep up to date with modern practice. Updating in key technologies is a specific activity to meet an identified commercial need.

28. The promotion of the economic and social impact of science and technology is an educational aim that should permeate the curriculum in order to strengthen the concept of scientific literacy and introduce the equally important concept of economic awareness.[14]

29. Many of the current initiatives such as problem solving, industrial and commercial liaison with schools and revision of science curricula in the school and further education sectors, have a major effect on the attitude of many students. These initiatives provide a foundation for changes in the whole education and training system. There are many initiatives to encourage a continuum of science and technology in education from primary stage onwards.

The systems approach

30. A systems approach[15] in education and training provides a means of reconciling the many competing demands on the timetable and encourages the study of the system followed by the functions of the components within that system. Sometimes known as the 'whole-to-part' method,[16] it has the advantage of emphasising the outcome of improved components and methods in the system as a whole. (For example, a domestic electric cooker may be used to demonstrate the concepts of energy transfer at the systems level, and the importance of design and value added in order to make a commercially viable product.)

31. A systems approach has also been developed to make effective use of human resources to meet variable marketing strategies, and it is already being incorporated into some engineering undergraduate and graduate courses.[17] This approach

considers a system in terms of layers of increasing detail, and is considered essential if modern manufacturing systems engineering is to be successfully and economically adopted. The engineer needs a broad background of engineering knowledge to deal with the overall issues and must have specific knowledge to deal with some of the relevant underlying layers of detail. A manufacturing systems engineering course covers the integration of the components of manufacturing operations and the most relevant manufacturing technology to produce marketable products with maximum efficiency.

Resources

32. A basic principle of the key technologies is that they have the potential to influence investment in the future. This applies as much to their introduction into the curriculum as to their introduction into the manufacturing process. Meanwhile, schools and colleges will require adequate resources if project work is to be expanded. Such facilities may be obtained from the reallocation of existing provision, but new funding will be needed from the LEAs or local industry, or central Government agencies such as DES, DTI or MSC.

33. Facilities for use of more sophisticated manufacturing or measuring equipment may be obtained from an FE college, a polytechnic or from a nearby industry. Schools and colleges should make full use of the opportunities that exist by means of 'link courses' and 'industrial placements'.

Keeping up to date

34. Many industrial companies are following The Engineering Council's recommendations[18] to carry out an annual review of their technical strategy, marketing and business plans in order to:

- develop new products to anticipate market opportunities;
- plan for the exploitation of new manufacturing technologies;
- be alert to future skill requirements;
- plan recruitment, training and retraining to meet changing needs.

35. It follows that industrial 'in house' training should be reviewed concurrently with other aspects of the business and technical strategy. Similarly, it may be in the interests of further and higher education institutions to consider their own need for a regular review of their activities.

36. The review should be prepared from an outsider's viewpoint so that interdisciplinary ideas are not missed. It should not be solely an update of previous reviews.

37. Through the Work-Related NAFE initiative, LEA colleges already have to review their programme of courses. This annual review of the academic year should contribute to the three-year rolling development plan. Similar requirements apply to higher education institutions. We recommend that during these reviews consideration should be given to:

- the changes in technology affecting existing programmes;
- the possible need for new programmes (both full-time and short courses for continuing education and training);
- the staff training implications of these changes.

Continuing education and training

38. Because of the rate of change of technology, it is essential that individuals keep ahead of new developments, especially in their own field. Engineers and technicians need to have a broad view of the world market and an understanding of how their roles influence the economic viability of their organisations. The provision of continuing education and training (CET) is a vital part in the process of ensuring that engineers and technicians keep up to date in their specialist field and in management and business skills. The education service has an important part to play in preparing individuals to adapt to change and undertake CET throughout their career.

39. FHE institutions are responding to the demand for CET by developing and running a variety of courses, often to meet specific local needs. These courses may vary in length from a few hours to several months. The development of CET courses is dependent on the providers identifying the requirements from industry and following this up by marketing the courses to industry. The PICKUP initiative is to be commended in this respect.[19]

40. The key technologies concept challenges organisations to assess their future technical direction and hence the technologies of most relevance to them. Providers of CET need to be equally responsive to rapidly changing industrial needs. However, it should be noted that while some high technology companies will be seeking out the latest development as their key technologies, many companies will have identified their key technologies in terms of older and more established ideas. These will still be innovative ideas for that company and will have a major evolutionary effect on their products and processes – and so improve their competitiveness.

41. The Engineering Council has suggested that

it would be good practice for providers of CET to:

'a) improve the methods of identifying emerging needs and, where necessary, design courses appropriately;

b) innovate by, for example, introducing more modular courses, distance learning techniques, distance learning centres and educational credit schemes;

c) collaborate with employers of engineers and technicians and also with other education and training organisations, for example, by sharing personnel and equipment;

d) encourage motivation by providing recognition and incentives to staff engaged in CET. Provide key staff with practical insight to industry/commerce by visits and attachments;

e) ensure you update your own technologists and technician staff involved in the teaching and training of CET.'[1]

42. To support the introduction of key technologies consideration should be given to the staff development of academic and support staff in all institutions. The inclusion of an interdisciplinary and innovative area of study such as key technologies should emphasise the need for a broader curriculum. Students will need not only to acquire the interpersonal skills involved in team working, but also learn the necessity of viewing new technical content in an economic context of added value. This may require specialist subject teachers and their support staff to take on additional skills.

43. The consideration of key technologies as an essential element of the curriculum means that more emphasis should be placed on the presentation of scientific fundamentals in initial engineering education, rather than 'bolting-on' new technology topics based on academic disciplines. Other skills should be included, such as systems thinking, group working, economic awareness (including finance, marketing and business skills) and the efficient application of modern design processes. National criteria for GCSE and 'A' level syllabuses should make provision for these principles and processes.

44. At post-school level the concept should be incorporated in the appropriate schemes of the various validating bodies to be accredited through NCVQ, and by the autonomous institutions in higher education. It is a concept that should permeate initial education and training, and should be a basis for continuing education and training for technicians and engineers.

45. The welcome trend in developing industrial/academic links has increased the need for industrial managers to communicate their requirements to the providers of education and training. Engineering is a multidisciplinary profession and engineers and technicians use their technical knowledge alongside their management and business skills. Personal qualities are often as important as technical ability, especially as engineers and technicians are often formed into project groups. Teachers and trainers should help to develop engineers' and technicians' appreciation of the commercial, social and cultural aspects of their work so that they are able to communicate effectively with their colleagues from other professions.

4 THE BROADENING OF THE CURRICULUM

46. The Engineering Council's policy statement *Standards and Routes to Registration* recognises the importance of interdisciplinary activities in the development of technicians and engineers. The integration of ideas is one of the characteristics of accredited courses for an Engineering Technician and is specified as:

> 'an introduction to good engineering practice and emphasis on practical problem-solving, bearing in mind the watchwords "integration" and "relevance" coupled with an introduction to using the latest technology and the exclusion of obsolete material and methods.'[19]

47. There will always be a need for specialists so education and training programmes must be sufficiently flexible to allow for the development of specialist skills. These should be learned more effectively if they are built upon a base of fundamental technological concepts. For practising engineers, this development may be facilitated through modular CET programmes. The NCVQ are developing a means of accrediting such activities where they are linked to qualifications. This may be either as a result of participation in college courses or by assessment of performance in the workplace.

The engineering core and key technologies

48. The FEU engineering core[20] provides a basis for the provision of a core curriculum in the training of technicians and engineers. This core is not specifically age related, nor is it exclusive to a particular branch or level of engineering as it aims to develop skills in relation to communication, planning, implementation and appraisal.

49. The accelerating rate of change of technology places emphasis on transferable skills at all levels. The checklist of core competences emphasises transferable skills in the technician's role while stressing the need for engineers to appreciate these competences in the formation of engineering teams. The core should provide a framework which permits engineers and technicians to work across rigid subject boundaries.

50. This broadening of the curriculum is an essential prerequisite in considering the implications of changing technologies. There is a need for individuals to receive a broad general education to which are added peaks of achievements in various specialisations. Concentration on teaching the fundamentals can avoid crowding of the curriculum by the inclusion of many specialist topics, some of which may only be relevant for a short time. There is good industrial support for the

education system to provide the broad base. Narrow specialisms can be built on this foundation as and when the needs arise. This may be through informal or formal CET, or perhaps a specialist course at a further education or higher education institution.

51. There is increasing demand by employers for staff who have learnt to deal with issues from across a wide range of subjects and who appreciate the significance of the overall strategy. It is also necessary for employees to know when specialist skills are required and outside assistance is necessary. According to Black and Harrison:

> 'Students should have the attributes of:
>
> – resources of knowledge, skill and experience which can be drawn upon, consciously or subconsciously, when involved in active tasks;
> – capability to perform, to originate, to get things done, to make and stand by decisions;
> – awareness, perception and understanding needed for making balanced and effective value judgements;
>
> if they are to be able to face an uncertain future.'[13]

52. This supports the flexible approach necessary to the learning of the key technologies: the concept of constantly reappraising needs in the light of new developments. The teaching of an example of a key technology is reviewed in Appendix 3.

5 CONCLUSIONS

53. This paper has been written to publicise the concept of key technologies and so facilitate a change of attitude amongst employers and providers of education and training. The concept can be reinforced if it is introduced and applied throughout the education system.

54. Attitudes are formed over a long period, and in a variety of environments. A positive change in attitude towards key technologies should be encouraged throughout the whole formal curriculum.

55. Evidence of the success of the incorporation of key technologies into the curriculum will be shown by an improvement in the supply and quality of engineers and technicians in British industry and, in the long term, a consequent increase in industrial competitiveness.

56. It is suggested that the concept of key technologies should be incorporated into the curriculum at all levels. At the basic level it does not necessarily require futuristic thinking, rather the retrospective analysis of the way in which economic growth and social benefit are inevitably linked with innovative technological development and teamwork. These principles and processes should be included in the various 'core' curricula, in the national criteria for GCSE and any revised 'A' level syllabuses. At post-school level the concept, including the need for review, should be incorporated in the appropriate schemes of the various validating bodies to be accredited through NCVQ, and by the autonomous institutions in higher education. It is a concept that should permeate initial education and training, and should be a basis for continuing education and training for technicians and engineers.

GLOSSARY

Accredited engineering course: An engineering course which meets the academic requirements set by The Engineering Council.

Added value: The difference between a company's sales revenue and its costs. As a guideline, the greater the added value, the more competitive the company will be.

BTEC: Business and Technician Education Council

CET: Continuing education and training (sometimes known as continuing professional development)

CPVE: Certificate of Pre-Vocational Education

Chartered Engineer (CEng): Engineers who are registered in the professional section of The Engineering Council's Register and who are corporate members of a nominated chartered engineering institution or an institution-affiliated body.

Competence: The possession and development of sufficient skills, knowledge, appropriate attitudes and experience for successful performance in life roles.

Competitiveness: The ability to carry out free trade at prices comparable to those of rival sellers.

Craftsman/woman: An individual who has a high level of skill in a specific trade.

Engineering Technicians (EngTech): Individuals, registered with The Engineering Council, who by virtue of their education and training and experience can demonstrate the application of proven techniques and procedures to the solution of practical problems with an element of personal responsibility. They usually work under guidance of CEng or TEng.

Engineers: Engineers acquire and use scientific, technical and other pertinent knowledge and skills to create, operate and maintain efficient systems, structures, machines, plant, processes and devices of practical and economic value.

Formation: The integrated package of academic education, structured training and experience in industry to prepare an engineer or technician to be qualified and ready to assume full responsibility.

GCSE: General Certificate of Secondary Education

Interdisciplinary: The area between disciplines.

Key technology: A newly emerging topic in science and engineering which is likely to have a major evolutionary effect on an existing product or process or may lead to a revolutionary new

product or process. The application of the key technology results in large increases in added value.

LEA: Local Education Authority

Multidisciplinary: The use of ideas from a range of disciplines.

NAFE: Non-advanced further education

NCVQ: National Council for Vocational Qualifications

PICKUP: The Department of Education and Science's Professional, Industrial and Commercial Updating Programme

SCSST: Standing Conference on Schools' Science and Technology

SSCR: Secondary Science Curriculum Review

System: An arrangement of components in an organised fashion.

Systems Approach: Working from the 'whole' to the 'part'.

TVEI: Technical and Vocational Education Initiative

Technician Engineers (TEng): Individuals registered with The Engineering Council who by virtue of their education, training and experience demonstrate that they can perform technical duties of an established or novel character either independently or under the general direction of more senior engineers.
(NB. Will probably be replaced by the term Incorporated Engineer during 1988.)

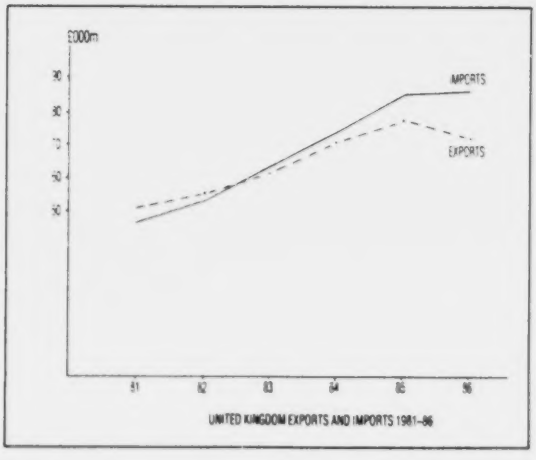
Technology: The application of science for industrial and commercial purposes.

Technical review: An appraisal of a company's technical strengths and weaknesses in relation to its marketing and financial strategy.

APPENDIX 1: THE IMPORT PROBLEM

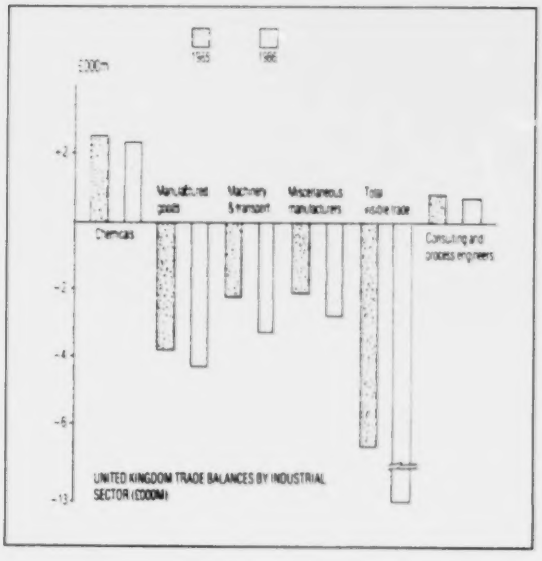
The apparent success of exports is outweighed by the import of technologically advanced manufactured goods. The UK is now a net importer of raw materials and manufactured goods.

EXPORTS AND IMPORTS 1981–1986

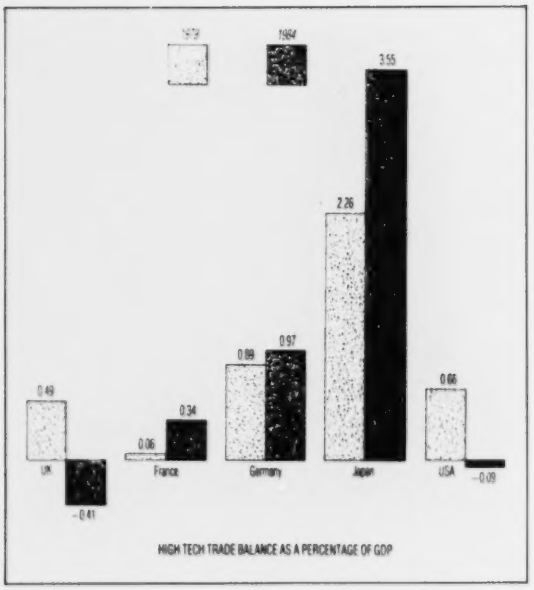


While the latest figures show that there has been an increase in exports of 6% during the first three months of 1987, over the corresponding period in 1986 imports have risen by 7%.

All industrial sectors are showing a worsening trade balance.



Source: Central Statistics Office *Monthly Digest of Statistics* July 1987



Source: Organisation for Economic Co-operation and Development (OECD)

International comparison shows the severity of the problem in the 'high tech' area which includes office machinery and computers, communication and electronic components, scientific instruments and electrical equipment.

APPENDIX 2: THE PROBLEM-SOLVING APPROACH

In the primary school, 'problem-solving' techniques are being introduced as a means of involving children with the challenges of technology, but without introducing technology as a formal subject. The problem-solving approach involves:

- recognising problems;
- discussing and thinking about solving them;
- trying out one solution;
- assessing how effective it is;
- perhaps modifying the solution in the light of experience.

(There is a marked similarity between this approach and the core competences.)

The benefits of such methods of instruction may include:

- team working;
- logical thought;
- mistakes are not seen as failures;
- confidence can be built from success;
- cross-curricular approach;
- appropriate for all abilities and both sexes;
- broad-based learning approach;
- part of real life.

If problem solving is to be part of the spiral curriculum leading to the exploitation of the key technologies, then economic awareness needs to be introduced at the appropriate levels. The financial aspects of a problem could be discussed with reference to material and labour resources, and the constraints of time and its financial implications.

The problem-solving approach, including action-centred learning, is also being used successfully at management schools to teach communication skills and as an introduction to elements of management.

APPENDIX 3: ROBOTICS AND ADVANCED MANUFACTURING TECHNOLOGY

A PRACTICAL EXAMPLE OF THE TEACHING OF A KEY TECHNOLOGY

Information technology and its applications are already influencing education. The specific example of the robot arm (which may form part of advanced manufacturing technology) has been the subject of several FEU papers:

Robotics: Guidance for Further Education (Longman for FEU, 1985)

Robotic Arms: A Contribution to the Curriculum (FEU, 1984)

CAD/CAM (Longman for FEU, 1985) A further education staff awareness programme. The associated staff development package is available from Gloucestershire College of Arts and Technology.

These papers illustrate the following encouraging points:

- educationists are introducing, teaching and developing the concepts of technology;
- the response time of the education system is being shortened to reflect changes in technology;
- disciplines such as robotics are not seen as ends in themselves. They are being taught in the context of industrial and commercial applications and not just in the traditional engineering areas.

By highlighting the key technologies it is hoped that reviews will be made of changing technological trends in order that the opportunities made available by these trends are not missed. Hence it is necessary to teach those techniques and basic principles which will apply to a wide range of activities. For example, the work undertaken by many schools and colleges in robotics provides the background to advanced manufacturing techniques and introduces control systems and software design.

The teaching of robotics demonstrates the key technologies at the components level which includes sensors, motors and actuators. These interdisciplinary ideas should be introduced into the curriculum.

REFERENCES

1. THE ENGINEERING COUNCIL. *A Call To Action: Continuing Education and Training for Engineers and Technicians* (Also Annexes A & B) 1986*

2. THE ADVISORY COUNCIL FOR APPLIED RESEARCH AND DEVELOPMENT. *Exploitable Areas of Science* 1986

3. INSTITUTE OF MANPOWER STUDIES. *Competence and Competition* MSC/NEDO, 1984

4. EDGE, G. *Engineering: A Strategy for Future Competitiveness* (An unpublished internal Engineering Council discussion paper) 1985

5. WHELAN, R. 'Knowing how to deal with know-how' in *The Engineer* 22 January 1987

6. FEU PROJECT RP286. 'Advanced Condition Monitoring by Acoustic Methods of Non-Destructive Testing'

7. KENWARD, M. 'The heat is on for superconductors' in *New Scientist* 7 May 1987

8. DEPARTMENT OF TRADE AND INDUSTRY. *A Programme for the Wider Application of New and Improved Materials and Processes* Report of the Collyear Committee, 1985

9. TECHNOLOGY REQUIREMENTS BOARD (DEPARTMENT OF TRADE AND INDUSTRY). *Focus on Innovation* 1987

10. BRUNER, J.S. *The Process of Education* Harvard University Press, 1960

11. THE ENGINEERING COUNCIL. *Problem Solving: Science and Technology in Primary Schools* 1985*

12. SSCR has produced a number of relevant titles, including the *Better Science* series published jointly by Heinemann Educational Books and the Association for Science Education. A complete list is available from SSCR, Newcombe House, 45 Notting Hill Gate, London W11 3JB.

13. BLACK, P. and HARRISON, G. *In Place of Confusion: Technology and Science in the School Curriculum* Nuffield-Chelsea Curriculum Trust/ National Centre for School Technology, 1985

14. See 'The PACE Curriculum Framework' in *Enterprise Education Bulletin* No. 3, FEU, 1986

15. NATIONAL ECONOMIC DEVELOPMENT OFFICE. *Manufacturing Systems Engineering: A Career for Tomorrow's World* 1986

16. FEU. *New Technology in Electrical Services* Longman for FEU, 1986

17. PARNABY, Dr. J. *The Design of Competitive Manufacturing Systems* 1986

18. THE ENGINEERING COUNCIL. *Technical Reviews for Manufacturing, Process and Construction Companies* 1983*

19. THE ENGINEERING COUNCIL. *Standards and Routes to Registration* 1984

20. FEU. *Core Competences in Engineering: An FEU View* 1985

* These publications are available free of charge from The Engineering Council.

SUGGESTIONS FOR FURTHER READING

THE ENGINEERING COUNCIL. *Continuing Education and Training: A National System for Engineering* The Engineering Council/DES PICKUP, 1988

INSTITUTE OF PERSONNEL MANAGEMENT. *A Partnership in Learning* DES, 1986

IFF RESEARCH LTD. *Adult Training In Britain* MSC, 1985

Many Further Education Unit publications are relevant to this subject. The FEU publications list is available from the FEU Information Centre.

This paper was prepared by a working party of:

Mr Jack Mansell M Ed C Eng	*Chief Officer, Further Education Unit, 1980–87*
Mr Albert Clyde MSc	*Development Officer, Further Education Unit*
Mr Bernard Dawkins BSc (Eng) C Eng	*Continuing Education and Training Executive, The Engineering Council*
Mr Anthony Price MA C Eng	*Industry Executive, The Engineering Council*

and is based on the work of the Technology and Product Design Committee and the Continuing Education and Training Committee of The Engineering Council. The assistance of many other people from industry and education is gratefully acknowledged.

The Engineering Council
10 Maltravers Street
London WC2R 3ER

01-240 7891

Further Education Unit
Elizabeth House
York Road
London SE1 7PH
01-934 9000